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PANASONIC HR-1800 HAND-HELD COMPUTER SOLUTIONS TO
COMPOSITE MATERIALS FOR (U) UNIVERSAL ENERGY SYSTEMS
INC DAYTON OH T N MASSARD ET AL SEP 83

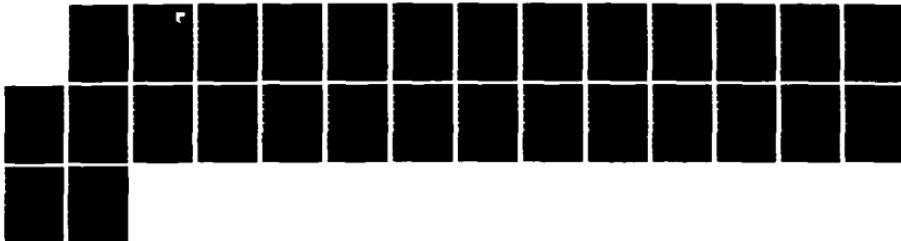
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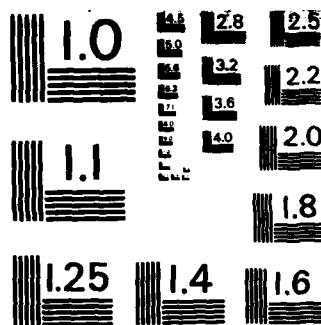
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PANASONIC HR-1800 HAND-HELD COMPUTER SOLUTIONS
TO COMPOSITE MATERIALS FORMULAS

Thierry N. Massard
Mechanics and Surface Interactions Branch
Nonmetallic Materials Division

and

Won J. Park
Universal Energy Systems, Inc.
Dayton, Ohio 45432

September 1983

Final Report for Period September 1982 - June 1983

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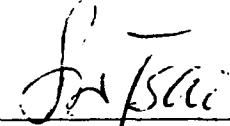
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This technical report has been reviewed and is approved for publication.



S.W. TSAI, Project Engineer & Chief
Mechanics and Surface Interactions Branch
Nonmetallic Materials Division

FOR THE COMMANDER



F. D. CHERRY, Chief
Nonmetallic Materials Division

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18. SUPPLEMENTARY NOTES This program uses the language of BASIC. The computer program(s) contained in this technical report is (are) theoretical and in no way reflect(s) any Air Force owned software programs.		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) BASIC Programming Composite Materials Properties of Unidirectional and Laminated Composite In-Plane and Flexural Stiffness and Strength Buckling of Orthotropic Simply Support Plate		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This volume contains the description and instructions of the use of Panasonic HR-1800 Hand-Held Computer for the key calculations of the stiffness and strength of symmetric laminated composites. Instant calculations can be made for practical use. The formulas and equation numbers used in the performed programming have been derived in a book entitled, <u>Introduction to Composite Materials</u> , co-authored by S. W. Tsai and H. T. Hahn, published by Technomic Publishing Company, Westport, Connecticut, July 1980.		

FOREWORD

This report was prepared in the Mechanics and Surface Interactions Branch (AFWAL/MLBM), Nonmetallic Materials Division, Materials Laboratory, Air Force Wright Aeronautical Laboratories, Wright-Patterson AFB, Ohio. This work was performed under Contract F33615-82-C-5001; SB5448-82-C-0086.

This time period covered by this report was from September 1982 to June 1983. Dr. Thierry N. Massard is a Visiting Scientist at the Materials Laboratory, Air Force Wright Aeronautical Laboratories, Wright-Patterson AFB, Ohio, and a Chief Engineer at the Commissari at L' Energie Atomique, Montrouge, France.

Dr. Won J. Park is a Senior Scientist from Universal Energy Systems, Inc. and Professor of Mathematics and Statistics at Wright State University.

The equations and table numbers which appear in the flow charts are the same as in Introduction to Composite Materials, co-authored by S. W. Tsai and H. T. Hahn, published by Technomic Publishing Company, Westport, Connecticut, in July 1980.



TABLE OF CONTENTS

SECTION	PAGE
I USER GENERAL INSTRUCTIONS	1
II CONTENTS OF THE PROGRAM	2
III PROCEDURE	3
1. Flow Diagram	3
2. Key Operation Procedure	4
3. Memory Contents	10
4. Sample Problems	12
5. Program Listing	18
IV CONCLUSIONS	22

SECTION I

USER GENERAL INSTRUCTION

- (1) The program language for HR-1800 Hand-Held Computer is BASIC from the Microsoft BASIC ROM attached to the computer.
- (2) The capacity of the computer is 8k RAM (model HR-1800). The printer is optional.
- (3) The program is called SYM-LAM (for symmetric laminates). The program considers only symmetric laminates of composite materials and is restricted to orthotropic materials for the buckling calculations.

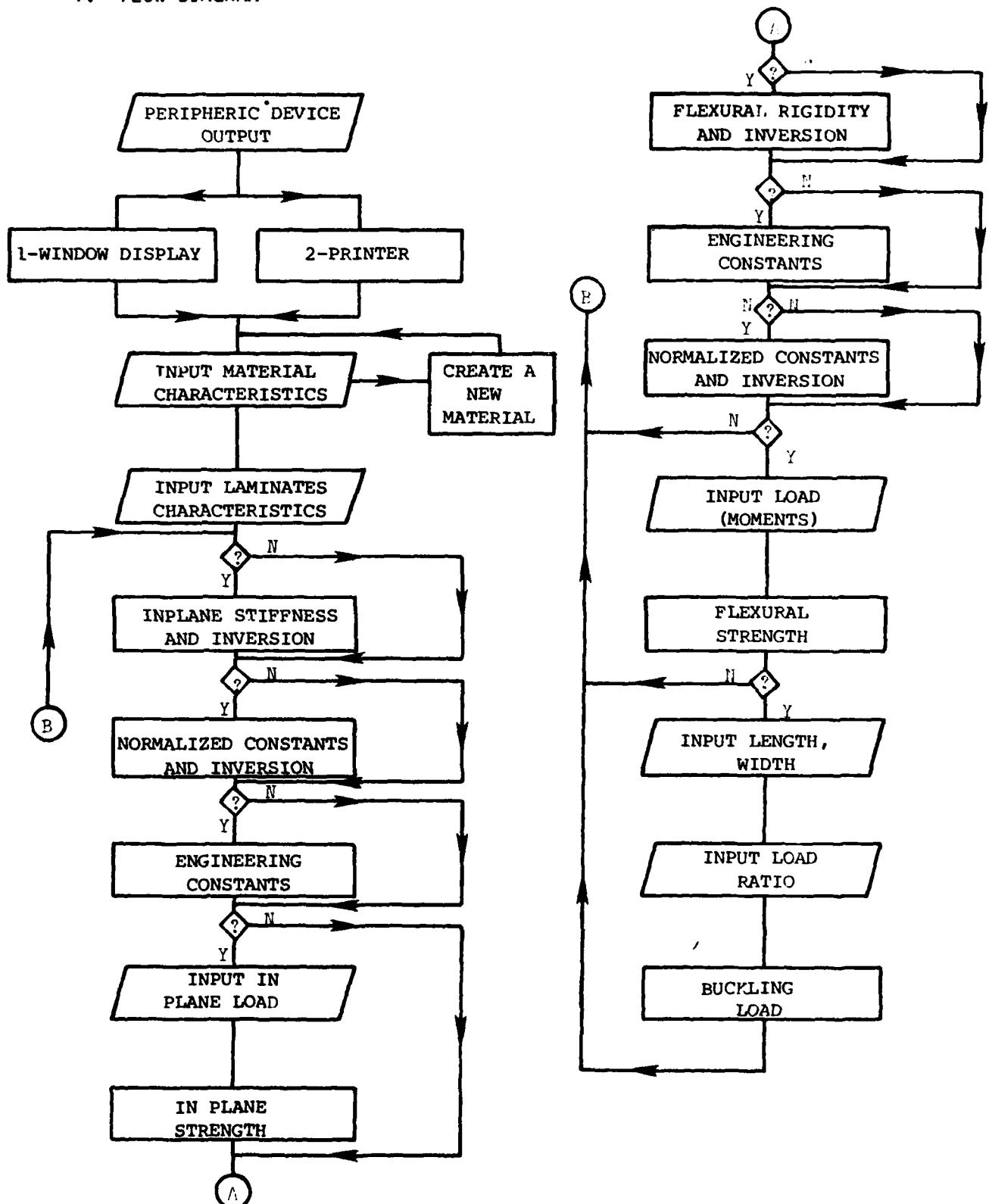
SECTION II
CONTENTS OF THE PROGRAM

The program performs scientific operations and computations of composite materials.

- (1) In-plane stiffness of symmetric laminates and matrix conversion.
- (2) Engineering constants.
- (3) Normalized in-plane stiffness and matrix inversion.
- (4) In-plane strength of symmetric laminates.
- (5) Flexural stiffness of symmetric sandwich plate and matrix inversion.
- (6) Engineering flexural constants.
- (7) Normalized flexural rigidity of sandwich plate and matrix inversion.
- (8) Flexural strength of sandwich plate.
- (9) Buckling load and modes of a simply supported rectangular plate subjected to two axial loads. (ORTHOTROPIC MATERIALS ONLY)
Reference: Mechanics of Composite Materials, R. M. Jones, MacGraw Hill .

SECTION III
PROCEDURE

1. FLOW DIAGRAM



2. KEY OPERATION PROCEDURE

Display	Operation	Print Out & Remarks
1 - LCD or 2 - printer	RUN ENTER 2 * ENTER M *	can be a function key f_1 or f_2 or f_3 1 will give results on the display window 2 will give results on the printer Available data (4 materials) 1-T300/5208 2-ALUMINIUM 3-KEVLAR/EPOXY 4-GLASS/EPOXY
Material (m for menu)?		Instructions to create new materials data TO INPUT A NEW MATERIAL (number N) - TYPE THE FOLLOWING LINE: 10*N DATA Ex, Ey, vx, Es, t, x X', Y, Y', S - INCREMENT N IN LINE 1820
Material (m for menu)?	1 * ENTER 2 *	the laminate can use only one material T300/5208 definition of the laminate
No. of angles	 ENTER 90 * ENTER 4 * ENTER 0 * ENTER 4 * ENTER	the laminate is $[0_4/90_4]_S$ layer nearer the midplane ***** ANGLE 1 = 0 Number of plies = 4 layer on the outside ***** ANGLE 2 = 90 Number of plies = 4
angle = ? number of plies = ?		
angle = ? number of plies = ?		

*user' choice

Display	Operation	Print Out & Remarks
Number of Core Plies? (flexural)	0 * [ENTER]	The core has no mechanical property. The ply thickness is the same than the laminate of the faces. n. of core plies = 0
In plane calculation -Y/N?	Y * [ENTER]	IN PLANE CONSTANTS STIFFNESS in MN/m A11 192.157298 A22 192.157298 A12 5.79384891 A66 14.34 A16 0 A26 0 ----- COMPLIANCE in m/KN a11 5.20880528 a22 5.20880528 a12 -.157053784 a66 69.7350069 a16 0 a26 0
Engineering CST Y/N?	Y * [ENTER]	ENGINEERING CONST. E1-o 95.991 GPa E2-o 95.991 GPa E6-o 7.17 GPa v21-o .03 v12-o .03 v61-o 0 v16-o 0 v62-o 0 v26-o 0

Display	Operation	Print Out & Remarks
Normalized Constants Y/N?	<input type="checkbox"/> Y* <input type="checkbox"/> ENTER	STIFFNESS in GPa A*11 96.0786488 A*22 96.0786488 A*12 2.89692445 A*66 7.17000001 A*16 0 A*26 0
		COMPLIANCE in TPa-1 a*11 10.4176106 a*22 10.4176106 a*12 -.314107569 a*66 139.470014 a*16 0 a*26 0
		IN PLANE STRENGTH
In plane strength Y/N?	<input type="checkbox"/> Y* <input type="checkbox"/> ENTER	N1 = 1 MN/m N2 = 0 MN/m N6 = 0 MN/m -----1 ----- angle 1 = 90 R+ = .746808548 n+ = 22 Sgm+ = 373.404274 MPa R- = 4.53828452 n- = 2 Sgm- = -2269.14226 MPa -----2 ----- angle 2 = 0 R+ = 1.36378965 n+ = 12 Sgm+ = 681.894823 MPa R- = 2.21547827 n- = 6 Sgm- = -1107.73914 MPa
N1 = (MN/m)?	<input type="checkbox"/> 1* <input type="checkbox"/> ENTER	
N2 = (MN/m)?	<input type="checkbox"/> 0* <input type="checkbox"/> ENTER	
N6 = (MN/m)?	<input type="checkbox"/> 0* <input type="checkbox"/> ENTER	

Display	Operation	Print Out & Remarks
Flexural calculations Y/N?	<input type="checkbox"/> Y* ENTER	<p>FLEXURAL CONSTANTS</p> <p>STIFFNESS in Nm</p> <p>D11 106.918678 D22 21.1861875 D12 1.93128297 D66 4.78000001 D16 0 D26 0</p> <p>-----</p> <p>COMPLIANCE in (Nm)-1</p> <p>d11 9.36832861 d22 47.2784122 d12 -.853994778 d66 209.205021 d16 0 d26 0</p>
Engineering CST Y/N?	<input type="checkbox"/> Y* ENTER	<p>ENGINEERING CONST.</p> <p>E1-- 160.113 GPa E2-f 31.726 GPa E6-f 7.17 GPa v21-f .091 v12-f .018 v61-f 0 v16-f 0 v62-f 0 v26-f 0</p>
Normalized CST Y/N?	<input type="checkbox"/> Y* ENTER	<p>STIFFNESS in GPa</p> <p>D*11 160.378016 D*22 31.7792812 D*12 2.89692445 D*66 7.17000001 D*16 0 D*26 0</p>

Display	Operation	Print Out & Remarks
<p>Flexural Strength Y/N?</p> <p>M1 = ? (MN)</p> <p>M2 = ? (MN)</p> <p>M6 = ? (MN)</p>	<p>Y*</p> <p>ENTER</p>	<p>COMPLIANCE in TPa-1</p> <p>d*11 6.24555241 d*22 31.5189415 d*12-.569329852 d*66 139.470014 d*16 0 d*26 0</p> <p>FLEXURAL STRENGTH</p> <p>M1 = 1 MN M2 = 0 MN M6 = 0 MN</p> <p>---- 1 ---- angle 1 = 90 R+ = 8.85874406E-04 Sgm+ = 253.81161 MPa R- = 4.31521825E-03 Sgm- = -7222.82739 MPa ---- 2 ---- angle 2 = 0 R+ = 7.9212116E-04 Sgm+ = 1188.18174 MPa R- = 1.13734025E-03 Sgm- = -1706.01038 MPa</p>

Display	Operation	Print Out & Remarks
Buckling Y/N?	Y ENTER	
Length & width in m?	1 ENTER .1 ENTER	BUCKLING dim. of the plate (l, w, t) is (1, .1, 2E-03) load ratio
Load N1, N2 in MN/m?	1 ENTER 0 ENTER	(N2/N1) is 0 critical load .133719444 MN/m 0 MN/m mode 5,1
In plane calculations. Y/N?		Load ratio is N2/N1. The dimension of the plate is: length, width, thickness. The buckling mode is given by mode i, j where i is the mode in length and j is the mode in width.
		The program restart to the first question. To study an other laminate strike key C1 (break) and F3 (RUN)

3. MEMORY CONTENT

MEMORY	DESCRIPTION	VERSION			MEMORY	DESCRIPTION	VERSION			MEMORY	DESCRIPTION	VERSION		
		1	2	3			1	2	3			1	2	3
A	E_x				KB	calculation				A(6)	v_{61}^0, v_{61}^f			
B	E_y				KC					A(7)	v_{16}^0, v_{16}^f			
C	v_x				KD					A(8)	v_{62}^0, v_{62}^f			
D	E_s				KE					A(9)	v_{26}^0, v_{26}^f			
E	h_0				TT	control variable				B(1)	N^+			
F	$m = (1 - v_x v_y)^{-1}$				XX	scale (10^a) factor				B(2)	N^-			
I	control variable				P	X				B(3)	σ^+			
J	"				Q	X'				B(4)	σ^-			
N	"				R	Y				T(1)	F_{xx}			
Z	"				S	Y'				T(2)	F_x			
CO	cosine θ				T	S				T(3)	F_{yy}			
SI	sine θ				U	calculation variable				T(4)	F_y			
TR	variable for trigonometric				A(1)	E_1^0, E_1^f				T(5)	F_{ss}			
TY	calculations				A(2)	E_2^0, E_2^f				T(6)	F_{xy}			
TX					A(3)	E_6^0, E_6^f				T(7)	G_{xy}			
TF					A(4)	v_{12}^0, v_{12}^f				T(8)	G_{yy}			
KA	constants for trigonometric				A(5)	v_{21}^0, v_{21}^f				T(9)	G_{xy}			

MEMORY	DESCRIPTION	VERSION			MEMORY	DESCRIPTION	VERSION			MEMORY	DESCRIPTION	VERSION		
		1	2	3			1	2	3			1	2	3
W1	G_{ss}				B\$(6)	"26"				V(1)	invariants of the G_{ij} tensor			
W2	G_x				B\$(9)	"E1-"				V(2)	"			
W3	G_y				B\$(10)	"E2-"				V(3)	"			
E1	ϵ_1				B\$(11)	"E6-"				V(4)	"			
E2	ϵ_2				B\$(12)	"v21-"				V(5)	"			
E6	ϵ_6				B\$(13)	"v12-"								
V(I)	$A_{ij} D_{ij}$				B\$(14)	"v61-"								
Y(I)	angle of each ply				B\$(15)	"v16-"								
Z(I)	number of plies for each angle				B\$(16)	"v62-"								
X(I)	calculations variable				B\$(17)	"v26-"								
A\$(1)	= "stiffness"				Z\$	output variable								
A\$(2)	= "compliance"				G\$	"Y", "N"								
B\$(1)	= "11"				U(1)	invariants of the Q_{ij} tensor								
B\$(2)	"22"				U(2)	"								
B\$(3)	"12"				U(3)	"								
B\$(4)	"66"				U(4)	"								
B\$(5)	"16"				U(5)	"								

4. SAMPLE PROBLEMS

C-1 T300/5208 $[0_1/90_1/\pm45_1]_s$
 4 core plies

$$N_1 = 1 \text{ MN/m} \quad N_2 = N_6 = 0$$

$$M_1 = 1N \quad M_2 = M_6 = 0$$

C-2 T300/5208 $[0_4/90_4]_s$
 no core

$$N_1 = 1 \text{ MN/m} \quad N_2 = N_6 = 0$$

$$M_1 = 0, \quad M_2 = 1N, \quad M_6 = 0$$

$$M_1 = 1N, \quad M_2 = 0 \quad M_6 = 0, \quad M_1 = 1MN, \quad M_2 = 0, \quad M_6 = 0$$

C-3 Kevlar/Epoxy Sandwich $[\pm30_4]_s$
 10 core ply

$$N_1 = 1 \text{ MN/m} \quad N_2 = N_6 = 0$$

$$M_2 = 1 \text{ MN} \quad M_2 = M_6 = 0$$

SAMPLE PROBLEM C-1

1 -T300/5208
 2 -ALUMINUM
 3 -KEVULAR/EP
 4 -GLASS/EPX

T300/5208
 ANGLE 1 = 0
 number of plies = 1
 ANGLE 2 = 90
 number of plies = 1
 ANGLE 3 = 45
 number of plies = 1
 ANGLE 4 = -45
 number of plies = 1
 n. of core plies = 4

IN PLANE CONSTANTS

STIFFNESS
 in MN/m
 A11 76.3682178
 A22 76.3682176
 A12 22.6073556
 A66 26.8804311
 A15 0
 A26 0

COMPLIANCE
 in 1/kN
 a11 14.3521976
 a22 14.3521976
 a12-4.24869459
 a66 37.2017843
 a15 0
 a26 0

ENGINEERING CONST.

E1-f 69.675 GPa
 E2-f 69.675 GPa
 E6-f 26.88 GPa
 v21-f .296
 v12-f .296
 v61-f 0
 v16-f 0
 v62-f 0
 v26-f 0

STIFFNESS
 in GPa
 A11 76.3682178
 A22 76.3682176
 A12 22.6073556
 A66 26.8804311
 A15 0
 A26 0

COMPLIANCE
 in TPa-1
 a11 14.3521976
 a22 14.3521976
 a12-4.2486946
 a66 37.2017843
 a15 0
 a26 0

IN PLANE STRENGTH

M1= 1 MN/m
 M2= 0 MN/m
 M6= 0 MN/m
 ===== 1 =====
 angle 1=-45
 R+= .347657121
 n+= 24
 Sg+=
 S47.657121 MPa
 R-= .677583674
 n- = 10
 Sg- =
 -677.583674 MPa

===== 2 =====
 angle 2= 45
 R+= .347657122
 n+= 24
 Sg+=
 347.657122 MPa
 R-= .677583674
 n- = 10
 Sg- =
 -677.583673 MPa

===== 3 =====
 angle 3= 90
 R+= .276743756
 n+= 30
 Sg+=
 276.743756 MPa
 R-= 1.31149767
 n- = 6
 Sg- =
 -1311.49767 MPa

===== 4 =====
 angle 4= 0
 R+= .58297431
 n+= 14
 Sg+= 582.97431
 MPa
 R-= .566515812
 n- = 14
 Sg- =
 -566.515812 MPa

FLEXURAL CONSTANTS

STIFFNESS
 in Nm
 D11 52.9323284
 D22 43.5553373
 D12 9.49191825
 D66 11.9845457
 D16 1.67446269
 D26 1.67446273

COMPLIANCE
 in (Nm)-1
 d11 19.716124
 d22 23.9837143
 d12-4.21341993
 d66 34.1293669
 d16-2.16601447
 d26-2.76227587

ENGINEERING CONST.

E1-f 76.079 GPa
 E2-f 62.542 GPa
 E6-f 17.829 GPa
 v21-f .213
 v12-f .175
 v61-f -.11
 v16-f -.026
 v62-f -.116
 v26-f -.033

STIFFNESS
 in GPa
 D11 79.3984926
 D22 65.3330059
 D12 14.2378774
 D66 17.9768185
 D16 2.51163403
 D26 2.5116941

SAMPLE PROBLEM C-1 (Cont'd)

COMPLIANCE

'n TPa-1
 d#11 13.1440826
 d#22 15.9891429
 d#12-2.80894662
 d#66 56.0862446
 d#16-1.44400964
 d#26-1.84151725

FLEXURAL

STRENGTH

M1= 1 MN
 M2= 0 MN
 M6= 0 MN
 ===== 1 =====
 angle 1=-45
 R+=
 4.12495439E-04
 Sgm+=
 618.743159 MPa
 R-=
 8.42675678E-04
 Sgm-=
 -1264.01352 MPa
 ===== 2 =====
 angle 2= 45
 R+=
 3.24260165E-04
 Sgm+=
 486.390249 MPa
 R-=
 7.4321028E-04
 Sgm-=
 -1114.81542 MPa
 ===== 3 =====
 angle 3= 90
 R+=
 2.28829112E-04
 Sgm+=
 343.243669 MPa
 R-=
 1.16682481E-03
 Sgm-=
 -1750.23723 MPa
 ===== 4 =====
 angle 4= 0
 R+=
 4.84691727E-04
 Sgm+=
 607.037591 MPa
 R-=
 4.57058315E-04
 Sgm-=
 -685.587474 MPa

BUCKLING

dim. of the
 Plate(l,w,t) 1
 .1 2E-03
 load ratio
 (N2/N1) is 0
 critical load:
 .252991111 MN/m
 0 MN/m
 mode 5 , L

SAMPLE PROBLEM C-2

1 -T300/5208
 2 -ALUMINIUM
 3 -KEVULAR/EP
 4 -GLASS/EPX

T300/5208

 ANGLE 1 = 0
 Number of Plies
 = 2

 ANGLE 2 = 90
 Number of Plies
 = 4
 n. of core
 Plies = 0

IN PLANE
 CONSTANTS

STIFFNESS

in MN/m
 A11 132.157298
 A22 132.157298
 A12 5.79384891
 A56 14.34
 A16 0
 A26 0

COMPLIANCE

in MM/m
 d11 5.20980525
 d22 5.20980528
 d12 -1.57953784
 d66 69.7350069
 d16 0
 d26 0

ENGINEERING
 CONST.

E1=95.991 GPa
 E2=95.991 GPa
 E3=7.17 GPa
 v21=0.03
 v12=0.03

v61=0
 v16=0
 v62=0
 v26=0

STIFFNESS

in GPa
 A11 96.0786488
 A22 96.0736488
 A12 2.39692445
 A66 7.17000001
 A16 0
 A26 0

COMPLIANCE
 in TPa-1
 d11 16.4176106
 d22 16.4176106
 d12 -3.14107569
 d66 139.470014
 d16 0
 d26 0

IN PLANE
 STRENGTH
 N1 = 1 MN/m
 N2 = 0 MN/m
 N6 = 0 MN/m
 =====
 angle 1 = 00
 R+= .746808548
 n+= 32
 Sg+=
 673.104274 MPa
 R-= 4.53828452

n- = 2
 Sgm- =
 -2269.14226 MPa
 =====
 angle 2 = 0
 R+= 1.36378965
 n+= 12
 Sgm+=
 681.394823 MPa
 R-= 1.21547627

n- = 6
 Sgm- =
 -1107.73914 MPa

FLEXURAL
 CONSTANTS

STIFFNESS
 in Nm
 D11 106.918678
 D12 21.1861075
 D12 1.33128297
 D66 4.78000001
 D16 0
 D26 0

COMPLIANCE
 in (nm)-1
 d11 9.36833561
 d22 47.2734122
 d12 -353994778
 d66 209.325021

d16 0
 d26 0

ENGINEERING
 CONST.

E1-f 160.113
 GFr
 E2-f 31.726 GFr
 E6-f 7.17 GPa
 v21-f .091
 v12-f .018
 v61-f 0
 v16-f 0
 v62-f 0
 v26-f 0

STIFFNESS
 in GPa
 D11 160.378016
 D22 31.7792312
 D12 2.39692445
 D66 7.17000001
 D16 0
 D26 0

COMPLIANCE
 in TPa-1
 d11 5.24555241
 d22 31.5139415
 d12 -5.69329852
 d66 139.470014
 d16 0
 d26 0

FLEXURAL
 STRENGTH
 N1 = 3 MN
 N2 = 1E-06 MN
 N6 = 0 MN
 =====
 angle 1 = 90
 R+= 318.180797
 Sgm+= 477271197
 MPa
 R= 555.029356

Sgm- =
 -322544036 MPa
 =====
 angle 2 = 0
 R+= 82.878661
 Sgm+= 124317992
 MPa
 R= 532.682322

Sgm- =
 -799024235 MPa

FLEXURAL
 STRENGTH
 N1 = 1 MN
 N2 = 0 MN
 N6 = 0 MN

SAMPLE PROBLEM C-2 (Cont'd)

```
===== 1 =====
angle 1= 90
R+=
8.35574406E-04
S3m+=
1253.81161 MPa
R-=
4.81521825E-02
S9m-=
-7322.32729 MPa
===== 2 =====
angle 2= 0
R+=
7.9312116E-04
S3m+=
1168.18174 MPa
R-=
1.13734025E-03
S9m-=
-1706.01038 MPa
```

```
-----  
FLEXURAL  
STRENGTH  
M1= 1E-06 MN  
M2= 0 MN  
M6= 0 MN  
===== 1 =====
angle 1= 90
R+= 935.974403
S9m+=
11539116.1 MPa
R-= 4815.21625
S3m+=
-72229273.3 MPa
===== 2 =====
angle 2= 0
P+= 732.12116
S9m+=
11381817.4 MPa
R-= 1137.34025
S3m+=
-17060103.8 MPa
```

```
-----  
BUCKLING  
dim. of the  
Plate(1,w,z)= 1
.1 2E-03
load ratio
(N2/N1) is 0
critical load:
.133719444 MN/m
0 MN/m
mode 5 , 1
```

SAMPLE PROBLEM C-3

	COMPLIANCE	ENGINEERING CONST.
1 - 7300/5208	in TP ₀ -1	
2 - ALUMINUM	d11 40.7712879	E1-f 19.745 GPa
3 - KEVLAR/EP	d22 180.908603	E2-f 4.578 GPa
4 - GLASS/EPX	d12-58.5970007	E6-f 11.933 GPa
KEYLAR/EP	d66 65.453584	V21-f 1.391
*****		V12-f .322
ANGLE 1 = 30	d16 0	V61-f -.217
number of piles	d26 0	V16-f -.131
= 4	-----	V62-f -.01
*****		V26-f -.025
ANGLE 2 =-30		-----
number of piles		
= 4		
n. of core	N1 = 1 MN/m	STIFFNESS
plies = 10	N2 = 0 MN/m	in GPa
-----	N6 = 0 MN/m	d11 30.8209058
IN PLANE	===== 1 =====	d22 9.56875392
CONSTANTS	angle 1=-30	d12 12.8151194
STIFFNESS	R+= .250398912	d66 12.6583173
in N/m	n+= 64	d16 5.27398345
d11 31.7789415	Sgm+=	d26 1.82048737
d22 10.6841775	125.199456 MPa	-----
d12 29.7275564	R-= .0900191266	COMPLIANCE
d66 30.5568044	n- = 176	in TP ₀ -1
d16 0	Sgm- =	d11 50.6433316
d26 0	-45.0095633 MPa	d22 218.398652
-----	===== 2 =====	d12-79.4551188
COMPLIANCE	angle 2= 30	d66 83.3644834
in MN/m	R+= .250398912	d16-10.9674482
d11 20.385644	n+= 64	d26-2.05500108
d22 20.4543013	Sgm+=	-----
d12-29.2985003	125.199456 MPa	FLEXURAL
d66 32.726792	R-= .0900191266	STRENGTH
d16 0	n- = 176	M1 = 1 MN
d26 0	Sgm- =	M2 = 0 MN
-----	-45.0095633 MPa	M6 = 0 MN
ENGINEERING	===== 1 =====	===== 1 =====
CONST.	FLEXURAL	angle 1=-30
STIFFNESS	CONSTANTS	R+=
in GPa	STIFFNESS	4.5630055E-04
d11 45.3894708	in Nm	Sgm+=
d22 10.3420887	d11 238.721254	125.200163 MPa
d12-14.8637782	d22 55.0689752	R-=
d66 15.2780022	d12 93.5179382	1.49437463E-04
d16 0	d66 96.1240974	Sgm- =
d26 0	d16 40.0493119	-44.2777579 MPa
-----	d26 13.824326	===== 2 =====
STIFFNESS	COMPLIANCE	angle 2= 30
in GPa	in (Nm)-1	R+=
d11 45.3894708	d11 6.6690807	3.44895089E-04
d22 10.3420887	d22 28.7603163	Sgm+=
d12-14.8637782	d12-9.27804033	122.131137 MPa
d66 15.2780022	d66 11.0438826	R-=
d16 0	d16-1.44427301	1.37431411E-04
d26 0	d26-2.70617426	Sgm- =
-----		-40.7204179 MPa

EXPLTING
dim. of the
float(1.0 m) 1
.1 4.5E-03
load ratio
(N2/N1) 1.0
crit. cons load:
2.08863557 MN/m
0 MN/m
mode 5 1

4. PROGRAM LISTING

The program, when running, utilizes the whole 8k RAM (1117 bytes free before running, only two bytes free when running).

The program has two subroutines to perform trigonometric functions (SINE & COSINE). This part could be skipped by using the scientific ROM which could be attached on the hand-held computer. This ROM was not available at the time when we made the program.

The program can be saved on a programmable external memory, to transfer the software on other computers. No cassette or disc interface is built in the hand-held computers.

PROGRAM LISTING

```

3 ATTACH 68 TO
*2
10 INPUT "1-LCD
20
2-Printer"IC
30 DIM
40 A$(10),B$(9),Z$(9)
50 V(12),A$(2),B$(17)
60 G$(3)
70 DATA
80 "11","22","12",
90 "66","16","26"
100 "","E1-","E3
110 "E6-","V21-"
120 "V12-"
130 DATA
140 "V61-","V16-","
150 "V2-","V26-"
160 DATA
170 "T300/5208",131
180 E3,.10,3E3,.28,7
190 E3,.125E-3,1
200 500,1500,40,246
210
220 DATA
230 "ALUMINUM",.69E
240 3,.69E3,.3,26.5E
250 3,1,400,400,400
260 ,400,230
270 DATA
280 "KEVLAR/EP",.76E
290 3,5.5E3,.34,2.3
300 E3,.125E-3,1400
310 235,12,53,34
320
330 DATA
340 "GLASS/EPX",.38,
350 6E3/8.27E3,.26,
360 4,14E3,.125E-3,
370 1026-.610,31,118
380
390 INPUT
400 "MATERIAL n for
410 menu":G$
420 RESTORE
430 :FOR I=1 TO
440 :READ
450 B$(I):NEXT I
460 N= VAL
470 (G$):IF
480 G$="n"THEN N=4
490 FOR I=1 TO
500 N:READ
510 A$(9),A,B,C,D,E
520 ,P,Q,R,S,T
530 IF
540 G$="n"THEN
550 FRINT
560 *Z$(I)-":A$(0)
570 1835 NEXT I:IF
580 G$=""THEN
590 GOTO 1850
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PROGRAM LISTING (Cont'd)

```

5000 FOR I=1 TO
3:XX=1E-3:IF
I>3 THEN LET
XX=1:U$=""
5050 IF ABS
A(I)-X1E-6
THEN LET A(I)=0
5100 PRINT
#2:3$(I+8)+Z$;1
E-3:INT
(1E3*A(I)*XX):U
5
5150 NEXT
I:RETURN
5400 GOSUB
2000:X$=""Z$=""
0:IN=2:TT=6:XX=
1E3:U$="m/kN":I
F I$="y":THEN
GOSUB 3800
5300 GOSUB
13000
5900
Z$="o":INPUT
"engin.
const.-g/n
":G$:IF
G$="y":THEN
GOSUB 4970
6000 INPUT
"norm.
const.d/n":G$
6050
Z$="a":N=1:TT=
0:IN=1E-3:U$="G
P:"
6060 IF
G$="y":THEN
GOSUB
12000:GOSUB
3800
6150
Z$="a":N=2:TT=
6:XX=1E6:U$="TP
":I:IF
G$="y":THEN
GOSUB
1800:GOSUB
12400
6200 GOTO 13000
6300 FOR I=1 TO
6:IN=0:NEXT
I:RETURN
7000 GOSUB
50000:TX=2*Y(1)
:GOSUB
50100:S2=TR:GOS
UB 50120:C2=TR
7010
TX=4*Y(1):GOSUB
50100:S4=TR:GOS
UB 50120:C4=TR
7020
7100
X(1)=U1+C2*U2+C
4*U3
7200
X(2)=U1+C2*U2+C
4*U3
7300
X(3)=U4+C4*U3
7400
X(4)=U5+C4*U3
7500
X(5)=S2*U2/2+S4
6*U3
7600
X(6)=S2*U2/2+S4
6*U3:RETURN
3000
DT=U(1)*U(2)*U(3)
+U(2)*U(3)*U(6)*
U(5)-U(2)*U(5)*
2-U(1)*U(6)*2-U
4*U(3)*2
3200
U(7)=(U(2)*U(4)
-U(6)*2)/DT
3250
U(8)=(U(1)*U(4)
-U(5)*2)/DT
3300
U(9)=(U(5)*U(6)
-U(3)*U(4))/DT
3400
U(10)=(U(1)*U(2)
-U(3)*2)/DT
3500
U(11)=(U(3)*U(6)
-U(2)*U(5))/DT
3600
U(12)=(U(2)*U(5)
-U(1)*U(6))/DT
3:RETURN
12000
A(1)=1/X(10)/V(1)
A(2)=1/X(10)
A(3)=1/X(10)/V(10)
12100
A(4)=-V(9)/V(7)
A(5)=-V(9)/V(8)
A(6)=V(11)/V(7)
12200
A(7)=V(11)/V(10)
A(8)=V(12)/V(9)
A(9)=V(12)/V(10):RETURN
12300 FOR J=1
T2
6:IN(J)=U(J)/X(1)
0:IN(J+6)=U(J+6)
*V(10):NEXT
J:RETURN
12400 FOR J=1
T2
6:IN(J)=U(J)/X(1)
0:IN(J+6)=U(J+6)
*V(10):NEXT
J:RETURN
13000 INPUT
"3*length
":L:IF
G$="y":GOTO
27000
13200 GOSUB
51000:PRINT
#2:PRINT #2:IN
PLANE
3*LENGTH:PRINT
#2
13400
Z$="N":U$="MN":B
E1=2:Z1=1:IF
PRINT
G$+" "+U$+" "+B
13500 INPUT
NM/I-10:PRINT
#2:G$+NM/I-10:IN
U$:NEXT
I:RETURN
14000
E1=V(1)*NM/I-1+M
(9*NM/2)-V(12)
*NM/3
14300
E2=V(9)*NM/I-1+M
(3*NM/2)+V(12)
*NM/3
14400
E3=V(11)*NM/I-1+
V(12)*NM/2+V(1
9)*NM/3:RETURN
14500 FOR I=1
T2
G$+H$="angle":ST
R$":I":IF
15000 GOSUB
15500:NEXT
I:GOTO 27000
15500 GOSUB
50000:TX=2*Y(1)
:GOSUB
50100:S2=TR:GOS
UB 50120:C2=TR
15550
TX=4*Y(1):GOSUB
50100:S4=TR:GOS
UB 50120:C4=TR

```

PROGRAM LISTING (Cont'd)

```

:5600      16800 PRINT      50SUB      40063
G1=V1+C2*V2+C4*  
V3      *Z;"Sg="      3800:GOSUB      TV=TK'M=I N=J
15650      "16(4);"MPa":RE      12400      40065 NE'NT
G2=V1-2*V2+C4*V  
3      17000 INPUT      31000 INPUT      J:NE'NT I
15700      "flex.      "strength &n  
G3=V4-C4*V3      calculations      "G$;IF      40070 PRINT
15750      -y/n";G$;X$="FL      32000      *Z;"critical
G4=v5-C4*V3      EXURAL      51200 GOSUB      load;"TT";Pn="
15800      CONSTANTS      51050:PRINT      AT"CL=1;TM=1
G5=52*V2/2-E4*V  
3      52000      #Z;"FLEXURAL      mode;"TM1";"AT
15900      53000:X(10)=Z(0)      53100      1:RETURN
*E      53700 FOR I=1      53500      50000
16000      TO 5:GOSUB 7000      53700      F=2E-16:R=1.576
J1=1:W2=V3+C4*V  
3-W3:V1=V2      53800      73633:B= INT
W3-C2*(V2-V3)      53950      53100      (3.141592652*2-
/2:V3=V2+C2-W3      4*(10)=X(10)+E*Z      16):I=.314159265
):/      54000      53100      E:J=301 E4
16100      54700      53200      50070
A=G1*E1^2+G2*E2      54800      53300      H=-.1666666667
^2-G4*E6^2+2*(G  
2*E1*E2+G5*E1*E  
6+G6*E2*E6)      54900      53400      =.3333333333E-11
16100      55000      54000      =.357652599E-3
3=J1*E1+J2*E2+J  
3*E6      55100      54100      50390
16200      P1=(-3+SQR  
(3*B+4*A))/2/A      55200      J=-.3544082232E-
16300      R2=(-3-SQR  
(3*B+4*A))/2/A      55300      31K=.275229711E
16400      B(1)= INT      55400      -51L=-.233333346
((10)/E/R1/2+1      55500      4E-7:RETURN
):/2      55600      50100
16450      B(2)= INT      55700      TV=TK*3.1415926
((10)/E/R2/2+1      55800:GOSUB      51100:TV= -4B
):/2      55900      51500:NEXT I
16470      B(3)=R1/X(10):B      56000      53100 INPUT
((1)=R2/X(10)      56100      "BUCKLING
16520 PRINT      56200      53200      53100:G$;IF
*Z;"====";I;"  
=====      56300      G$;"Y";THEN
16530 PRINT      56400      5310:GOSUB      53150:IF TV =B
*Z;H$;Y(I)      56500:GOTO 3400      THEN PRINT
16550 PRINT      56600      5310:GOSUB      error:STOP
*Z;"R+=";R1      56700      53100      50160:THE: INT
16560 IF A(1)<1      56800      57000      (T)K<.5
THEN 16650      56900      51000:PRINT      50170
16600 PRINT      57000      57100      *T;"BUCKLING";T
*Z;"n+=";B(1)      57200      Y=1E33
16650 PRINT      57300      50110 INPUT      57300:IF TT= INT
*Z;"Sg+=";B(3)      57400      "length & width
16700 PRINT      57500:GOSUB 12000      57400:IF T= THEN
*Z;"R-="; ABS  
(R2)      57600 INPUT      57500:IF T<0
16730 IF A(1)<1      57700      "load N1,N2 in
THEN 16800      57800      MN/M";TK,L      57600:TR=4B
16750 PRINT      57900      40025 PRINT      (T)-TNO; -TNO
*Z;"n- = "; ABS  
(B/2)      58000      *Z;"dim. of the
16800      58100      P-plate";L,W,T      58000:IF T>0
16850 PRINT      58200      "B;C;2*W;T"      58100:TR= T
*Z;"n- = "; ABS  
(B/2)      58300      d ratio N2/N1
16900      58400      L:TK      58200:TR=4B
16950      58500      40040 FOR I=1      (T)-TNO; -TNO
*Z;"n- = "; ABS  
(B/2)      58600:FOR J=1 TO 5:J=0
17000      58700      58700      5:J=(I/B)^2+(J/
17050      58800      58800      C)^2*L/K
17100      58900      40050      40050:IF TR>0
17150      59000      59100      TV=4B*2*(B*(I/
17200      59200      59300      B)-4B*V(I-2)*(V(I
17250      59400      59500      3)-2*B*V(I-1)*(V(I
17300      59600      59700      1/2)-2*B*V(I)*(V(I
17350      59800      59900      1/2)^4)
17400      60000      40060:IF TX>TY      40060:IF TX>TY
17450      60100      THEN 40065      THEN 40065
17500      60200      51000      50240 RETURN
17550      60300      51000      51000 IF Z=1
17600      60400      51050 PRINT      THEN RETURN
17650      60500      *Z;"  
="" RETURN

```

SECTION IV
CONCLUSIONS

The description and the instructions for the use of the Panasonic HR-1800 Hand-Held Computer, the calculations of the stiffness and strength of symmetric laminates, are presented in this report. This package has been made very easy to use and requires no previous knowledge. Instant calculations can be made for practical use.

END

SEARCHED

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